

Complex plan verification and planning using domain constraints in realistic domains

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Goal

Develop necessary theory and software modules for

- verifying of complex plans
- planning using domain constraints

in realistic domains.

Simplistic vs. Realistic

- Actions have no duration (or same duration)
- Effects are observable immediately after action execution
- Fluents are Boolean
- Complete information
- Resource or temporal constraints are not considered
- Complex plans are conditional plans (if-then)

Simplistic

- Actions have fixed or non-fixed duration
- Delayed and continuous effects are allowed
- Continuous fluents
- Incomplete information
- Resource constraints, temporal constraints, other constraints
- Complex plans can contain loop and branches

Realistic

Technical Approach

- Use of Declarative Logic Programming (DLP) for representation and reasoning about actions
 - uniform solution to the ramification and qualification problem without any compilation
 - no difficulty when fluent dependencies contain cycles
- Exploit different types of domain constraints to obtain efficiency in planning
 - temporal
 - hierarchical
 - procedural [**if .. then ..else, while .. do, procedure ...**]
- Action description language with an independent automata based semantics for realistic domains
 - formulating plan correctness
- Use of complexity analysis in making choices

NASA Relevance

- Automatic verification and (semi) automatic generation of control.
- Contributions towards reliable software agents.
- Contributions towards rapid development of software agents.

Accomplishments to date

- A transition function based theory of actions with continuous fluents, resources, and actions with duration and delayed effects – language ADC (KR'02).
- Action theories with probability (AAAI'02).
- Complexity of model checking for knowledge update (KR'02).
- Planning with Golog+HTN+temporal constraints in simplistic domains. (Submitted to journal, preliminary version: LPNMR'01).
- Experimenting with procedural constraint in Web Services composition (KR'02).
- Planning with sensing actions in simplistic domains (Submit)
- A book on DLP with a chapter on planning, plan verification, and expression of causality using DLP (Cambridge University Press).
- Summary of 2001: 2 IJCAI, 2 LPNMR, 1 AIJ, 2 other journal papers.

Language ADC

a causes $f = \text{val}(f_1, \dots, f_n, t)$ from t_1 to t_2	Continuous fluent & effect	actions w. fixed duration
a contributes $\text{val}(f_1, \dots, f_n, t)$ to f from t_1 to t_2	Additive fluents	
a initiates p from t_1	Starting a process	actions w. non-fixed duration
a terminates p from t_1	Terminating a process	
p associated_with $f = \text{val}(\dots)$	'simple' effects	
p associated_with $f \leftarrow \text{val}(\dots)$	Additive effects	
a needs r_1, \dots, r_m	Resources constraints	

Example

Fixed Duration

drive(v,10) **causes** gasInTank = gasInTank - .03 vt **from 0 to 10**

drive(v,10) **causes** distance = vt **from 0 to 10**

drive(v) **initiates** gasReduce(v) **from 0**

drive(v) **initiates** distanceIncrease(v) **from 0**

stop **terminates** gasReduce(v) **from 0**

stop **terminates** distanceIncrease(v) **from 0**

gasReduce (v) **associated_with**

gasInTank = gasInTank - 0.03 vt

distanceIncrease(v) **associated_with** distance = vt

Non-Fixed Duration

Timeline

- Evaluating ADC against other languages (Dec 02)
- Experimenting ADC with real-life domains (Dec 02/Jun03)
- Goal languages for realistic domains (Dec 02)
- Planning in ADC with domain constraints (Jun03)
- Extending ADC to allow static causal laws, exogenous actions, continuous precondition, uncertainty (Jun03)
- Use of DLP and complexity analysis: in parallel with the above.

Current investigation

- Planning and plan verification in domains with actions with durations, continuous effects, resource constraints (prototype for plan verification in DLP available)
- Evaluating and extending ADC

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Goal: Develop necessary theory and software modules to verify complex plans and to plan using domain constraints in realistic domains.

Objectives:

- To consider realistic domains where actions have durations, fluents may be multi-valued, there may be incomplete knowledge, there may be sensing or knowledge producing actions, qualification and ramification constraints etc.; and do planning in such domains after developing the necessary theory to do hypothetical reasoning about actions in such domains.
- Taking into account the intractability of planning, develop languages to express different kinds of domain constraints, such as temporal, partial ordered and hierarchical (as in. HTNs), procedural (as in GOLOG), and reactive rule based; and develop planners that exploit such domain knowledge.
- Verify complex plans – after developing the necessary theory, that may contain features such as conditionals, and sensing actions which are necessary to deal with incompleteness.
- Use declarative logic programming (DLP) to express causality (leading to ramification and qualification) that is hard to eliminate in domains such as circuits – both electrical and hydraulic, and incorporate it in planning and plan verification.
- Analyze the complexity of the above tasks so as to guide us to make correct choices, and look for approximations.

Key Innovation:

- Use of DLP in expressing causality, plan verification, and fast prototyping of problem solving activities.
- Expanding the domain constraint types.
- Action theory for realistic domains formulating plan correctness.
- Use of complexity analysis in making choices.

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Accomplishments to date:

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- Summary 2001: 2 IJCAI, 2 LPNMR, 1 AIJ, 2 other journal papers.

Schedule:

- Implementation of ADC (Jun 03)
- Evaluating ADC against other languages (Dec 02)
- Experimenting ADC with real-life domains (Dec 02/Jun03)
- Planning in ADC with domain constraints (Jun03)
- Extending ADC to allow static causal laws, exogenous actions, continuous precondition (Jun03)
- Goal languages for complex domains (Dec 02)
- Planning with sensing actions in simplistic domain (Dec 02)
- Use of DLP and complexity analysis: in parallel with the above.